Larval development of *Cryptolithodes expansus* Miers (Decapoda: Anomura: Lithodidae) reared in the laboratory

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Abstract.—The complete larval development of Cryptolithodes expansus Miers is described based on laboratory rearing. The species has four zoeal stages and a megalopa. The larvae are described and illustrated, and detailed comparisons are made with other lithodid larvae, particularly those of Cryptolithodes typicus Brandt.

Cryptolithodes expansus Miers, 1879 is found along the Korean coast (personal observation) and in Japan (Makarov 1938, 1962) on rocky bottoms in the sublittoral region to a depth of about 50–60 m. The family Lithodidae is represented by 16 genera and 95 species (Dawson 1989), but the larval development of only 16 species, representing 9 genera, has been described (Konishi 1986; Haynes 1984, 1993; Konishi & Taishaku 1994).

Sars (1890) described all zoeal stages up to the megalopa of Lithodes maja Linnaeus, 1758. Subsequent studies of Lithodidae larvae have been described, at least in part, for 15 species (Konishi 1986; Haynes 1984, 1993; Konishi & Taishaku 1994): Cryptolithodes typicus Brandt, 1848, Dermaturus mandtii Brandt, 1850, Hapalogaster grebnitzkii Schalfeew, 1892, H. dentata (De Haan 1844), H. mertensii Brandt, 1850, Lithodes aequispina Benedict, 1895, L. antarctica Jacquinot, 1853, Lopholithodes mandtii Brandt, 1848, Paralithodes brevipes (H. Milne Edwards & Lucas, 1841), P. camtschaticus (Tilesius 1815), P. platypus (Brandt 1850), Paralomis granulosa (Jacquinot 1852), P. hystrix (De Haan 1846), Placetron wosnessenskii Schalfeew, 1892, and Rhinolithodes wonessenskii Brandt, 1848.

Hart (1965) described all zoeal stages, megalopa and crab 1 stage of *Cryptolitho*-

des typicus Brandt, 1848 reared in the laboratory. This is the only species of Cryptolithodes for which larvae are known so far. The purpose of the present study is to describe complete larval stages of C. expansus reared in the laboratory, and to compare them with those of C. typicus.

Materials and Methods

On 20 August 1995 a local fisherman caught three berried females of *Cryptolithodes expansus* with a commercial octopus trap in the vicinity of Pusan (35°10'N, 129°10'E), Korea. The ovigerous females were brought to the laboratory, and kept in a container filled with running sea-water. On 10 March 1996, about 250 larvae hatched from one of the females. Of these, 60 were individually reared in 50 ml glass bottles placed in an incubator at 9.5– 10.5°C. Some larvae were kept in 11 glass beakers for mass culture.

Larvae were fed with newly hatched Artemia nauplii. Moulting and mortality were checked daily. After checking, the larvae were transferred to freshly prepared bottles and beakers. At each developmental stage, dead larvae and exuviae were fixed and preserved with 3% neutralized formalin solution. At least five specimens of each stage were dissected in ethylene glycol for microscopic observation. Drawings were made with the aid of a drawing tube.



Fig. 1. *Cryptolithodes expansus* Miers. Survival and duration of larval stages reared under laboratory conditions of 9.5–10.5°C and 31.80–32.65‰.

Measurements taken were: carapace length (CL), from the anterior tip of the rostrum to the postero-median margin of the carapace; total length (TL), from the anterior tip of the rostrum to the postero-median margin of the telson excluding telson processes. At least five specimens were measured using a calibrated ocular micrometer.

Results

Development and duration of the larvae.—Cryptolithodes expansus passed

Table 1.—*Cryptolithodes expansus* Miers. Duration of each larval stage reared at $9.5 \sim 10.5^{\circ}$ C and $31.80 \sim 32.65\%$.

	Duration of larval stages (day)		
Larval stages	Mean	Range	п
Zoea I	4.8	3–7	47
Zoea II	8.9	6-18	42
Zoea III	8.2	6-17	29
Zoea IV	14.8	13-16	18
Megalopa	10.5	7-15	3

through four zoeal stages and a megalopa (Table 1, Fig. 1). Of the 60 larvae reared individually, only three molted to the megalopa stage within approximately 37 days.

Descriptions First Zoea.

Size: CL = 1.6-1.8 mm (mean 1.6 mm);TL = 4.0-4.4 mm (mean 4.1 mm).

Duration: 3–7 days.

Color: dark brown color uniformly diffused over the whole carapace.

Carapace (Fig. 2A, B): rostrum well-developed, tapering from broad base to acute tip; ventral and posterior carapace margins with submarginal furrow and raised rim; postero-lateral margin smoothly rounded.

Eyes (Fig. 2A, B): sessile.

Abdomen (Fig. 2 A, B): narrow and slender; 5 somites plus telson; 3rd–5th somites with pair of lateral spines; pair of minute spines on postero-dorsal margin of 2nd–5th somites.

Telson (Fig. 2L): armed with 7 pairs of marginal processes; outermost a naked spine; 2nd a fine hair; 3rd–7th denticulate spines.

Antennule (Fig. 2C): biramous; an endopodal bud naked, a delineated exopod with 10 aesthetascs.

Antenna (Fig. 2D): biramous; scaphocerite of the protopod with 6 long plumose setae and 2 minute naked setae; endopod naked, tapering to sharp terminal point, a spine adjacent to the endopod.

Mandible (Fig. 2E): stout and well armed with median teeth; mandibular palp present as a small bud.

Maxillule (Fig. 2F): coxal endite with 7 serrated and 1 naked spinnule; basial endite with 7 stout denticulate spines and 2 minute setae; endopod 3-segmented with 2+1+3setae.

Maxilla (Fig. 2G): proximal and distal lobes of coxal endite with 7 and 4 setae respectively; proximal and distal lobes of basial endite with 4 setae each; endopod unsegmented with 3 subterminal and 5 terminal setae; scaphognathite with 10 plumose setae.

First maxilliped (Fig. 2H): coxa naked; basis with 2, 2, 3, 3 setae, endopod 5-segmented with 3, 2, 1, 2, 4+1 setae; exopodite with 4 terminal plumose natatory setae.

Second maxilliped (Fig. 2I): coxa naked; basis with 1, 2 setae; endopod 4-segmented with 2, 2, 2, 4+1 setae; exopod with 4 plumose natatory setae.

Third maxilliped (Fig. 2J): biramous; endopod unsegmented; exopod two-segmented.

Pereiopods (Fig. 2K): elongate but not functional appendages; first pair subchelate.

Second Zoea

Size: CL = 2.1-2.2 mm (mean 2.2 mm); TL = 4.4-5.0 mm (mean 4.8 mm).

Duration: 6–18 days.

Carapace (Fig. 3A, B): slight increase in size, but no change in armature.

Eyes (Fig. 3A, B): stalked and movable.

Telson (Fig. 3L): unchanged.

Antennule (Fig. 3C): similar to first zoea exopod with 9 aesthetascs of varying size.

Antenna (Fig. 3D): exopod with 7 plumose setae and 1 minute naked seta.

Mandible (Fig. 3E): some teeth added.

Maxillule (Fig. 3F): setation of endites and endopod unchanged.

Maxilla (Fig. 3G): proximal and distal lobes of coxal endite with 9 and 4 setae respectively; proximal and distal lobes of basial endite with 5 and 4 setae respectively; endopod unsegmented, with 3 subterminal and 5 terminal setae; scaphognathite with 22 plumose setae.

First maxilliped (Fig. 3H): setation of basis unchanged; 1 plumose lateral seta added on 1st-3rd segments of endopod; exopod with 8 plumose natatory setae.

Second maxilliped (Fig. 3I): setation of basis unchanged; 1 plumose lateral seta added to 1st to 3rd segments of endopod; exopod with 8 plumose natatory setae.

Third maxilliped (Fig. 3J): biramous; endopod bud with 3 setae; exopod with 8 plumose natatory setae.

Pereiopods (Fig. 3K): unchanged in armature; slight increase in size.

Pleopods (Fig. 3B): rudimentary uniramous buds on somites 2nd-5th.

Third Zoea

Size: CL = 2.2-3.2 mm (mean 2.6 mm); TL = 4.9-5.9 mm (mean 5.4 mm).

Duration: 6–17 days.

Carapace (Fig. 4A, B): similar to second zoea.

Telson (Fig. 4L): unchanged.

Antennule (Fig. 4C): exopod with 9 aesthetascs.

Antenna (Fig. 4D): endopod much longer than scaphocerite.

Mandible (Fig. 4E): some teeth added.

Maxillule (Fig. 4F): setation and shape unchanged.

Maxilla (Fig. 4G): proximal and distal lobes of coxal endite with 8 and 4 setae respectively; basial endite unchanged; en-



Fig. 2. *Cryptolithodes expansus* Miers. First zoea. A, Dorsal view; B, Lateral view; C, Antennule; D, Antenna; E, Mandible; F, Maxillule; G, Maxilla; H, First maxilliped; I, Second maxilliped; J, Third maxilliped; K. Pereiopods; L, Telson. Scale bars = 0.2 mm.



Fig. 3. *Cryptolithodes expansus* Miers. Second zoea. A, Dorsal view; B, Lateral view; C, Antennule; D, Antenna; E, Mandible; F, Maxillule; G, Maxilla; H, First maxilliped; I, Second maxilliped; J, Third maxilliped; K; Pereiopods; L, Telson. Scale bars = 0.2 mm.

dopod unsegmented, with 3 subterminal and 4 terminal setae; scaphognathite with 24 plumose setae.

First maxilliped (Fig. 4H): setation unchanged.

Second maxilliped (Fig. 4I): setation unchanged.

Third maxilliped (Fig. 4J): setation unchanged.

Pereiopods (Fig. 4K): unchanged.

Pleopods (Fig. 4B): well developed but not functional appendages.

Fourth Zoea

Size: CL = 3.0-3.4 mm (mean 3.2 mm); TL = 6.1-6.9 mm (mean 6.4 mm).

L = 0.1 - 0.9 mm (mean 0.4 mm

Duration: 13–16 days.

Carapace (Fig. 5A, B): similar to third zoea.

Telson (Fig. 5T): unchanged.

Antennule (Fig. 5C): similar to previous stage.

Antenna (Fig. 5D): endopod 2-segmented and much longer than exopod.

Mandible (Fig. 5E): some teeth added.

Maxillule (Fig. 5F): setation of coxal endite and endopod unchanged; basial endite with 8 stout denticulate spines and 2 setules.

Maxilla (Fig. 5G): setation of coxal and basal endite unchanged; scaphognathite with 26 plumose setae.

First maxilliped (Fig. 5H): setation unchanged.

Second maxilliped (Fig. 5I): setation unchanged.

Third maxilliped (Fig. 5J): more developed than in third zoea.

Pereiopods (Fig. 5K–O): uniramous; 1st pair unchange; 2nd–4th with apical spine except on 5th.

Pleopods (Fig. 5P–S): unchanged.

Megalopa

Size: CL = 2.4-2.5 mm (mean 2.5 mm);TL = 3.6-3.8 mm (mean 3.7 mm).

Duration: 7-15 days.

Color: intense scarlet.

Carapace (Fig. 6A, B): triangular in dorsal view, with conical rostrum, convex in transverse section; cervical groove distinct; angle between lateral carapace and pleuron acute, with well-marked keel projecting laterally.

Abdomen (Fig. 6A, B, O): 6 somites plus telson; 2nd–5th segments with pleopods; 6th segment with 3 minute hairs on the distal margin.

Telson (Fig. 6O): naked; more elongate and conical; twice as long as 6th abdominal segment.

Antennule (Fig. 6C): biramous; lower ramus 2-segmented with 0, 3+3 setae; upper ramus 4-segmented with 0, 4, 3, 3 aesthetascs plus 3 terminal setae.

Antenna (Fig. 6D): scale naked; flagellum 8-segmented with 0, 2, 0, 0, 4, 1, 4, 4 setae.

Mandible (Fig. 6E): strongly chitinized, smooth and not toothed as in zoeal stages, with broad blade-like process; palp 2-segmented.

Maxillule (Fig. 6F): endites with minute spines; endopod unsegmented.

Maxilla (Fig. 6G): setae of coxal and basial endite reduced and tooth-like; endopod unsegmented; enlarged scaphognathite with 47 plumose setae.

First maxilliped (Fig. 6H): basis with 8 setae; endopod unsegmented and with 5 setae; exopod with 4 terminal setae.

Second maxilliped (Fig. 6I): basis with 2 setae; endopod 4-segmented with 0, 0, 0, 2 setae; exopod 2-segmented with 0, 4 setae.

Third maxilliped (Fig. 6J): basis with 1, 1 setae; endopod 5-segmented with 4, 6, 5, 14, 9 setae; exopod with 3 long plumose setae.

Pereiopods (Fig. 7A–E): well developed and armed with spines; functional chelipeds.

Pleopods (Fig. 6K–N): present on 2nd– 5th abdominal somites; endopod small and naked; exopods with 9–11 plumose natatory setae.

Discussion

Morphological characteristics of lithodid larvae have been discussed by Gurney



Fig. 4. *Cryptolithodes expansus* Miers. Third zoea. A, Dorsal view; B, Lateral view; C, Antennule; D, Antenna; E, Mandible; F, Maxillule; G, Maxilla; H, First maxilliped; I, Second maxilliped; J, Third maxilliped; K, Pereiopods; L, Telson. Scale bars = 0.2 mm.

(1942), MacDonald et al. (1957), Pike & Williamson (1960), Kurata (1964), and Konishi (1986). They implied that larval morphology of this family was very similar

to that of the Paguridae, except for the reduction or disappearance of uropods.

Although the genus *Cryptolithodes* belongs to the family Lithodidae, it differs



Fig. 5. *Cryptolithodes expansus* Miers. Fourth zoea. A, Dorsal view; B, Lateral view; C, Antennule; D, Antenna, D_1 - D_2 , Endopods of antenna; E, Mandible; F, Maxillule; G, Maxilla; H, First maxilliped; I, Second maxilliped; J, Third maxilliped; K, First pereiopod; L, Second pereiopod; M, Third pereiopod; N, Fourth pereiopod; O, Fifth pereiopod; P, Pleopod of second abdominal segment; Q, Pleopod of third abdominal segment; R, Pleopod of fourth abdominal segment; S, Pleopod of fifth segment; T, Telson. Scale bars = 0.2 mm.

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Fig. 6. *Cryptolithodes expansus* Miers. Megalopa. A, Dorsal view; B, Lateral view; C, Antennule; D, Antenna; E, Mandible; F, Maxillule; G, Maxilla; H, First maxilliped; I, Second maxilliped; J, Third maxilliped; K, Pleopod of second abdominal segment; L, Pleopod of third abdominal segment; M, Pleopod of fourth abdominal segment; N, Pleopod of fifth abdominal segment; O, Telson. Scale bars = 0.2 mm.

VOLUME 113, NUMBER 1



Fig. 7. *Cryptolithodes expansus* Miers. Megalopa. A, First pereiopod; B, Second pereiopod; C, Third pereiopod; D, Fourth pereiopod; E, Fifth pereiopod. Scale bars = 0.2 mm.

		Species		
	Characters	C. typicus (Hart 1965)	C. expansus (Present study)	
First Zoea				
Size*	carapace length	1.4 mm	1.6 mm	
	total length	3.0 mm	4.1 mm	
Antennule	aesthetascs	8	10	
Antenna	endopod	sharp tip, minute subterminal tooth.	sharp tip	
Maxillule	basial endite	7 setae	9 setae	
	endopod	7 setae	9 setae	
Maxilla	proximal lobes	8, 6 setae	7, 4 setae	
Telson	posterior margin	round	straight	
Second Zoea				
Antennule	aesthetascs	8	9	
Antenna	endopod	segmented	unsegmented	
Maxillule	basial endue	8 setae	9 setae	
	endopod	1+1+3 setae	2+1+3 setae	
Third Zoea				
Antenna	endopod	segmented	unsegmented	
Fourth Zoea				
Antenna	endopod	segmented	segmented	
Maxillule	basial endue	9 setae	10 setae	
Megalopa				
Size*	Carapace length	2.0 mm	2.5 mm	
	Total length	2.9 mm	3.7 mm	
Carapace	rostrum	wide and flattened	narrow and pointed	
Abdomen	5th segment	2 spines	3 spines	
Antenna	flagellum	2+1+1+0+3+4+2+7 setae	0+2+0+0+4+1+4+4 setae	
Third maxil-				
liped	exopod	4 plumose setae	3 plumose setae	
Telson	shape	triangular	spaculate	

Table 2.—Comparison of morphological characters between C. typicus and C. expansus

* Measured from Hart (1965, fig. 1 I, fig. 3)

morphologically from other lithodid larvae. The larvae of *Cryptolithodes* spp. resemble those of some Diogenidae and Coenobitidae in that they lack lateral carinae on the postero-lateral margins of the carapace. Major morphological characteristics of lithodid larvae as reported by Konishi (1986) are as follows: "Uropods, if present, lack an endopod, even in the final zoeal stage; the third maxilliped has an endopod in the first zoeal stage; abdominal somites lack mediodorsal spines; the telson without an anal spine."

Comparative morphological features of *Cryptolithodes typicus* and *C. expansus* are summarized in the Table 2. The larvae of *C. expansus* differed from those of *C. typicus* in body size, number of antennular aesthetascs, setation of the maxillule, and segmentation of the second maxilliped in the zoeal stages.

The zoeal stages of *Cryptolithodes typicus* and *C. expansus* differ from those of the other lithodid larvae in the following: The abdomen is narrower and more slender, and composed of five segments plus telson in all the zoeal stages; uropods are absent in all the zoeal stages; a postero-lateral carinae on the carapace is absent in zoeal stages; a mandibular palp is present at the first zoeal stage.

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